Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_\_\_\_\_

**CALORIMETRY – Measuring Enthalpy Changes**

|  |  |  |
| --- | --- | --- |
| ΔH can be determined by 3 different methods: | | |
| **1. using Calorimetry** | 2. using Hess’s law | 3. using standard enthalpy of formation |

**1. Using Calorimetry:**

The heat of a reaction or ΔH is measured experimentally from

* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ •known \_\_\_\_\_\_\_\_\_\_\_\_\_ and •\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Calorimeter:**

* A device used to measure heat released or absorbed during a chemical reaction or a physical process.
* Ideally, an \_\_\_\_\_\_\_\_\_\_\_\_\_\_ system

|  |  |  |
| --- | --- | --- |
| **Types of calorimeters** | | |
| **Simple coffee cup calorimeter** | **Flame Calorimeter used to determine ΔH of Combustion** | **Bomb Calorimeter used to determine ΔH of Combustion** |
| * http://2012books.lardbucket.org/books/principles-of-general-chemistry-v1.0/section_09/5047b4653a4f636b2de270dee1eb0d36.jpgtwo nested polystyrene cups (excellent insulators) * **The reaction occurs in the water which contains a known mass of chemicals** * covered with a lid with 2 holes for a thermometer & a stirrer * air b/t 2 cups adds insulation * under constant pressure | * is flame resistant * The calorimeter absorbs a significant amount of heat and must be included in the energy calculation * Used to determine ΔH of combustion of food. | -more parts  - a closed system under constant P&V  - the assumption that heat loss is negligible must be made.  -The heat capacity of the bomb calorimeter takes into account the heat capacity of *all* the components of the bomb:  *C*bomb calorimeter = *C*water + *C*thermometer + *C*stirrer + *C*container |

**❄❄ ❄ Assumptions used in simple calorimetry:**

**1 Calorie = 1000 calories = 4184 J = amt of energy need to raise temp of 1g of H2O by 1oC**

The above assumptions lead to the following equations

|  |  |
| --- | --- |
| Exothermic processes | Endothermic processes |
| ∆Hgiven off by reaction  = \_\_\_\_\_\_\_\_\_\_\_\_\_\_  \_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_\_ | ∆Hgained by reaction  = \_\_\_\_\_\_\_\_\_\_\_\_\_\_  \_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_\_\_ |
| *\* reaction = rxn you’re studying inside the calorimeter \* System= water in the calorimeter* | |

**Hands-on activity 5.2 page 302- Determination of the Temperature of a Bunsen Burner Flame**

Introduction

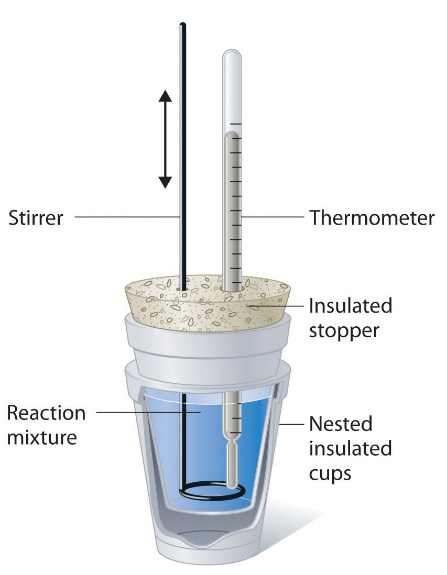
A Bunsen burner flame is clearly too hot to measure by ordinary means; however, we can estimate its temperature by applying calorimetry and the Law of Conservation of Energy.

A strip of copper is heated in the hottest blue region of the flame and then quickly transferred into a calorimeter containing water.

By measuring the temperatures of the copper strip, water and final temperature, the initial temperature of the hot copper strip can be calculated and then ascribed to temperature of the flame.

The calorimeter (“heat measurer”) will consist of two nested styrofoam cups set in a 250 mL beaker.

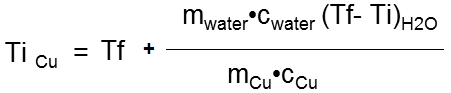
When the heated copper is dropped into the water, its heat is absorbed by the water.

The Law of Conservation of Energy allows us to state that heat lost by the copper equals the heat gained by the water:

- heat lost by copper = heat gained by water

Or -Qlost = Qgained

And - mCu•cCu • (Tf- Ti)Cu = mwater•cwater (Tf- Ti)H2O



🡪

**Materials**

|  |  |  |  |
| --- | --- | --- | --- |
| A long strip of Cu | Graduated cylinder | Stir rod | Metal tongs/tweezer |
| Simple calorimeter | Thermometer | Balance |  |

**Procedure**

* Measure 100 mL water into the calorimeter and measure its temperature.
* Ensure that thermometer stay submerged in the water.
* Weigh the copper strip and determine its temperature.
* Heat the copper strip for 5 minutes
* Turn off the burner and SLOWLY lift the cup so that the hot metal becomes immersed in the water.

Do not touch the water inside the cup with the tongs/tweezers. **Why?**

* Stir water briefly and record highest temperature obtained.

Data and Calculations:

1. Create a table for data collection in this experiment:
2. Determine the temperature of Bunsen burner using the data collected in this lab. (What exactly are you trying to determine here?)

You will need to use specific heat capacities: cwater = 4.18 J/g 0C cCu = 0.385 J/g 0C

1. What assumptions have you made when performing your calculations?

Follow up question:

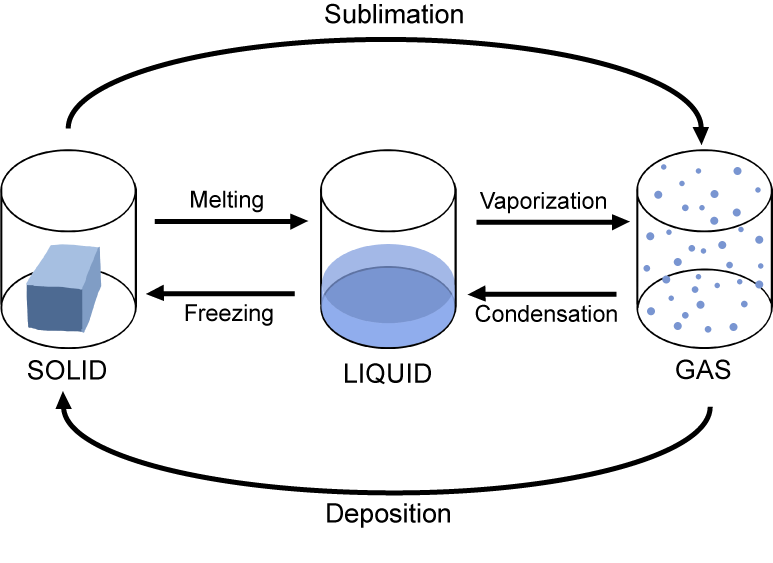
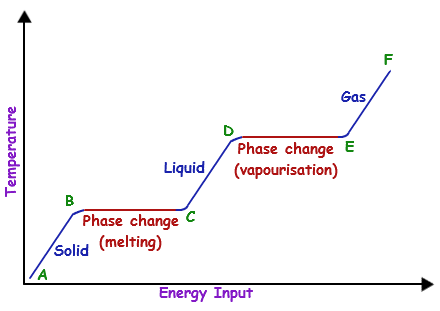
a) If 450 kJ of heat are added to 20 kg of aluminum, what temperature change would be expected? [25oC]

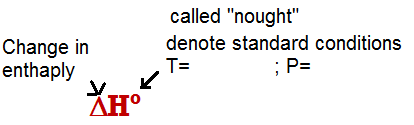
b) If the aluminum started at 30 0C, what would its final temperature be? [55oC

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**Enthalpy of physical processes (Phase Changes)**

* Heat (usually a substantial amount) must be added to or removed from a substance to change its phase



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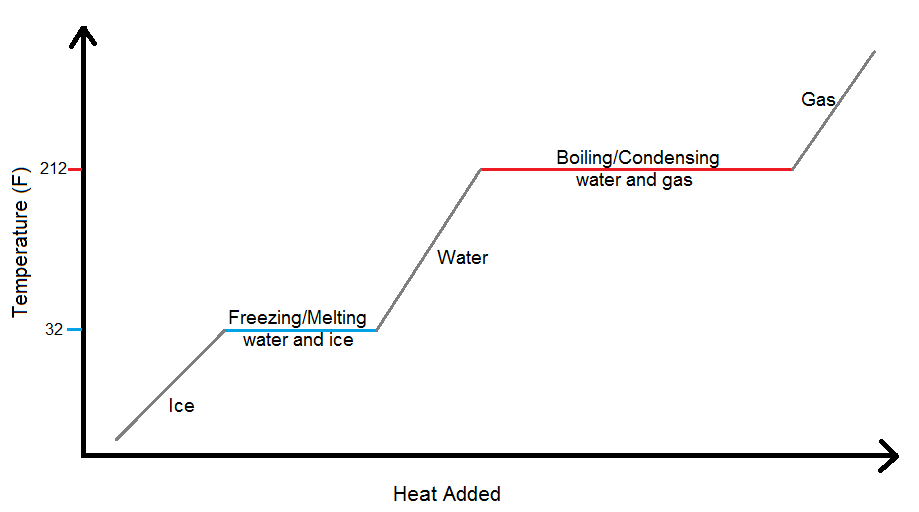
ΔHo= enthalpy change under standard conditions, with everything present in their standard states

**Different types of standard enthalpy for physical processes**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Symbol** | **ΔHo sol** | **ΔHo melt**  **also ΔHo fusion** | **ΔHo****fre**  **also ΔHo solidification** | **ΔHo****vap** | **ΔHo****cond.** |
| **Name** | **Enthalpy of solution** | **Enthalpy of melting** | **Enthalpy of freezing** | **Enthalpy of vaporization** | **Enthalpy of condensation** |
| **Meaning** | energy needed to \_\_\_\_\_\_\_\_\_\_\_\_ a solute in a solvent | energy needed to change a solid into a liquid | energy released when a liquid becomes a solid | energy needed to change a solid into a liquid | energy needed to change a solid into a liquid |

The Δ*H* for one phase change is the negative of the Δ*H* for the opposite phase change.

**∆H°melt = \_\_\_\_\_\_\_\_\_\_∆H°vap = \_\_\_\_\_\_\_\_\_\_**

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**Heating Curve for Water**

∆Hvap = 40.7 kJ/mol

∆Hcond = \_\_\_\_\_\_ kJ /mol

∆Hmelt = 6.01 kJ/mol

∆Hfreeze = \_\_\_\_\_\_kJ/mol

**How much heat is required to convert 45.0 g of ice at -115.00C into steam at 2200C?**

**Useful data for question 1 to 7.**

∆Hmelt = 6.01 kJ/mol ∆Hfre = -6.01 kJ/mol ∆Hvap = 40.7 kJ/mol ∆Hcond = -40.7 kJ/mol

1. Calculate the amount of heat needed to melt 40.0g of ice at 0°C [13.4 kJ]

1. How much energy is required to change 50.0g of water at 100°C to steam at 100°C? [113 kJ]
2. Calculate the enthalpy change when 500g of steam at 100°C condenses and cools to 35°C [-1263 kJ]
3. Calculate the amount of energy needed to change 0.20 kg of ice at -10°C to water at 20°C [88 kJ]
4. Calculate the amount of energy needed to convert 0.100kg of ice at -5.0°C to steam at 110°C [302 kJ]
5. *(Somewhat challenging)* A scientist places a block of ice at 0.0°C in a calorimeter. It gains 25.5 kJ of energy, causing the ice to melt and undergo and temperature change of 25.0°C. What mass of ice was added to the calorimeter? [58.1g]
6. How much heat is lost by 40g of ice when it cools from -5 0C to -15 0C? [-804 J]

**Different types of standard enthalpy for chemical processes**

|  |  |  |  |
| --- | --- | --- | --- |
| **Symbol** | **ΔHoneut** | **ΔHo comb** | **ΔHo r** |
| **Name** | **Enthalpy of neutralization** | **Enthalpy of combustion** | **Enthalpy of reduction** |
| **Meaning** | energy change in a neutralization reaction  e.g. NaOH + HCl 🡪 NaCl + H2O | energy change in a combustion reaction usually of a hydrocarbon  e.g. C2H5OH + O2 🡪 CO2 + H2O | Energy change in a reduction-oxidation reaction  e.g. AgNO3 + Cu🡪 (CuNO3)2 + Ag |

**Molar enthalpy**

= the enthalpy change per mole of a substance undergoing a physical or chemical change

**Formulas to know : n = m/M q = n x molarΔH q = mcΔT**

E.g. If enthalpy change for 2 mol of a reactant is 40 kJ, what will be the molar enthalpy?

**Using Calorimetry to find molar enthalpy:**

What given?

In a calorimetry experiment, 7.46g KCl is dissolved in 100.0mL (100.0g) water at an initial temperature of 24.1oC. The final temperature of the solution is 21 oC. What is the molar enthalpy of solution of KCl? Write a thermochemical equation.

**Example of calculating enthalpy of neutralisation:**

In a simple calorimeter, 200.0 mL of 1.00 M hydrochloric acid reacts with 100.0 mL of 1.50M solution of sodium hydroxide. The initial temperature of both solutions is 25.000C and the final temperature of the mixture after reaction is 30.000C. Determine the enthalpy change for the reaction and provide a thermochemical equation.

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**Example of calculating Enthalpy of combustion with data obtained from Calorimetry**

525 g of water initially at 25 °C is heated by the combustion of 0.850 g of methane. What will the final temperature of the water be? The molar enthalpy of combustion of methane is -890.7 kJ/mol.

What is given?

**More Calorimetry Practice Problems**

1. What mass of lithium chloride must have dissolved if the temperature of 200.0 g of water increased by 6.0 °C?

LiCl(s)  LiCl (aq)  + 37KJ. [5.9 g]

1. 5010 g of water is heated by the complete combustion of 2.00 mole of methane (CH4). If the water increases in temperature from 10**°** C to 95**°** C, determine the heat of reaction from the combustion. Write a thermochemical equation. [-1781.75 kJ]
2. The heat of combustion for butane (C4H10) is ΔHc = -2881.9 kJmol-1. If all of the heat from the combustion of 95.8 g of butane, C4H10, is used to heat up water, what mass of water can be heated from 22.0 °C to 50.0 °C [40.6 kg]
3. The molar enthalpy of solution of silver nitrate is +22.6 kJ/mol. If 5.9 g of silver nitrate is dissolved into 5.0 g of water, what will be the change in temperature? [37.5 °C]

5. In a simple calorimeter, 50.0 mL of 0.300 M copper(II) sulfate reacts completely with 50.0 mL solution of sodium hydroxide. The initial temperature of both solutions is 21.400C and the final temperature of the mixture after reaction is 24.600C. Determine the enthalpy change for the reaction and provide a thermochemical equation.

[ -1.34 KJ] [-89kJ/mol CuSO4]